Exchange, rearrange, and change: Dynamic ecosystem processes along the Western Antarctic Peninsula (WAP)

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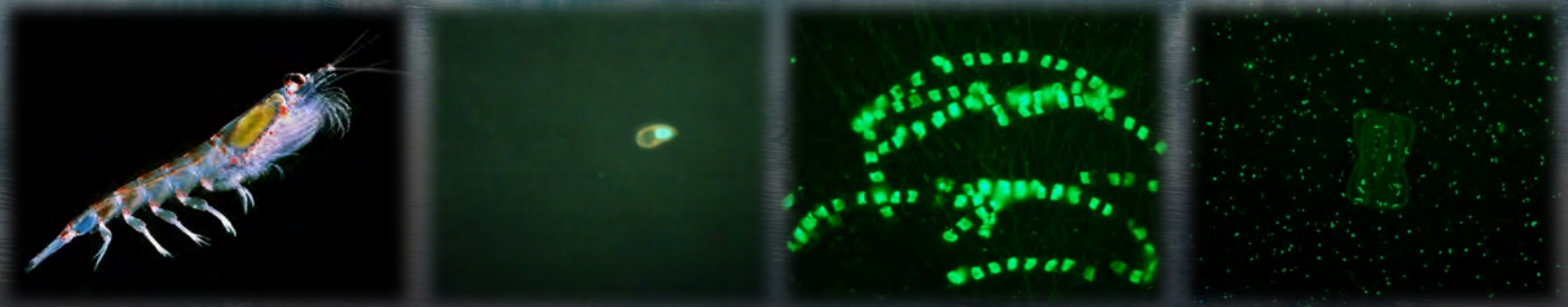
- Exchange: An introduction to the WAP marine environment
- Rearrange: A seascape unit view of WAP ecosystem dynamics
- Change: Gene expression analysis of light acclimation during the winter-spring seasonal transition



Exchange: An introduction to the western Antarctic Peninsula

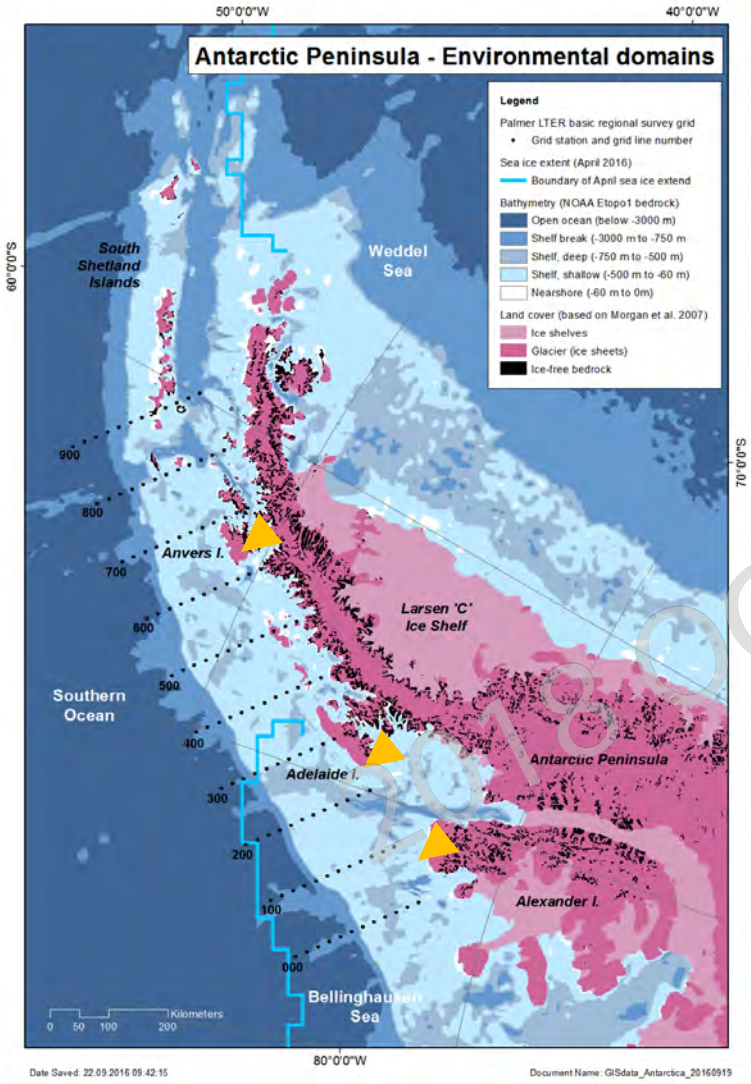
The subpolar South Shetland Islands

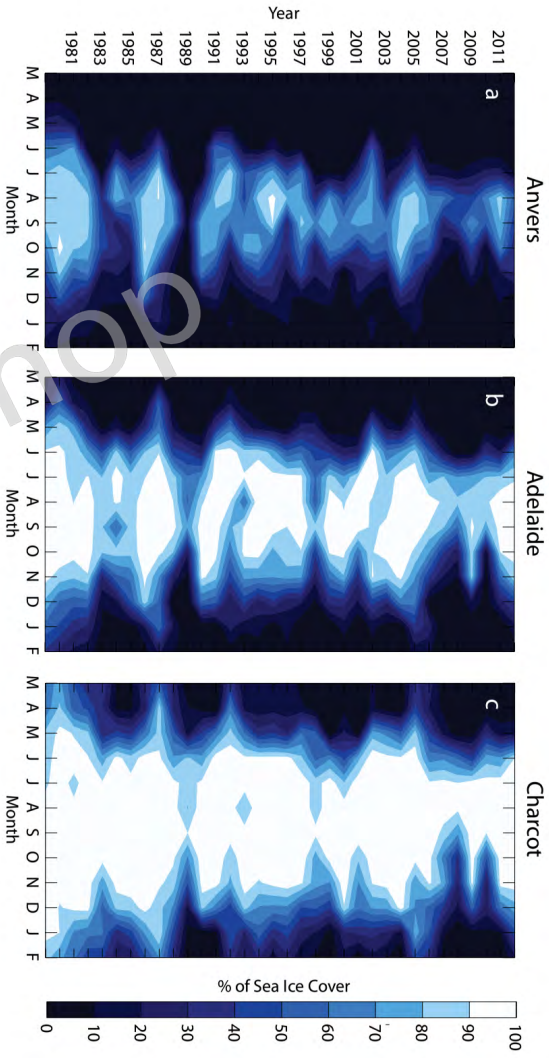
Polar Charcot Island

NASA/Goddard Space Flight Center Scientific Visualization Studio

- The WAP is recognized as one of the most rapidly warming places on Earth
- The location of the WAP near the sea ice edge means that it is vulnerable to very small perturbations
- Are we seeing an exchanging of the polar WAP ecosystem with a subpolar ecosystem?

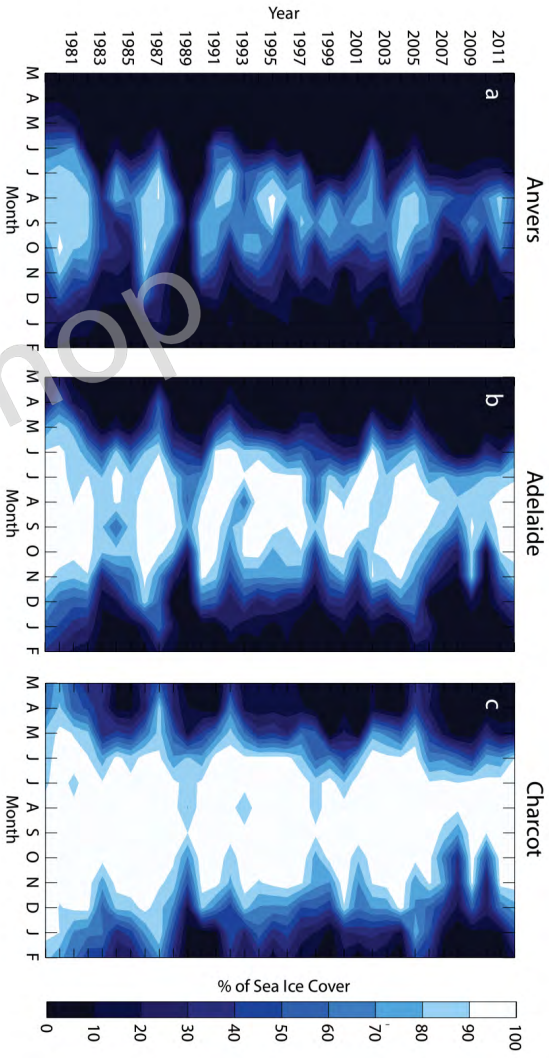
Introduction to the western Antarctic Peninsula





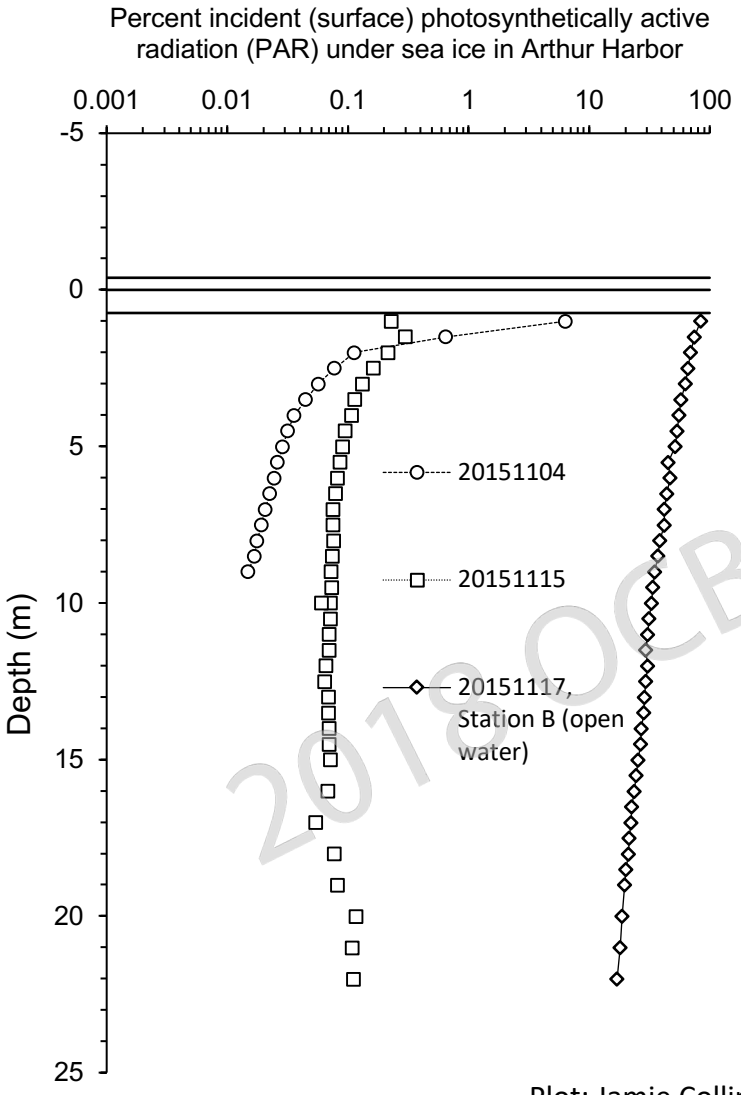
Ducklow et al. 2013

- There has been a noticeable decline in sea ice extent since 1981 across the central WAP, though sea ice has been higher most recently
- Changing sea ice cover exerts multiple influences on the WAP ecosystem

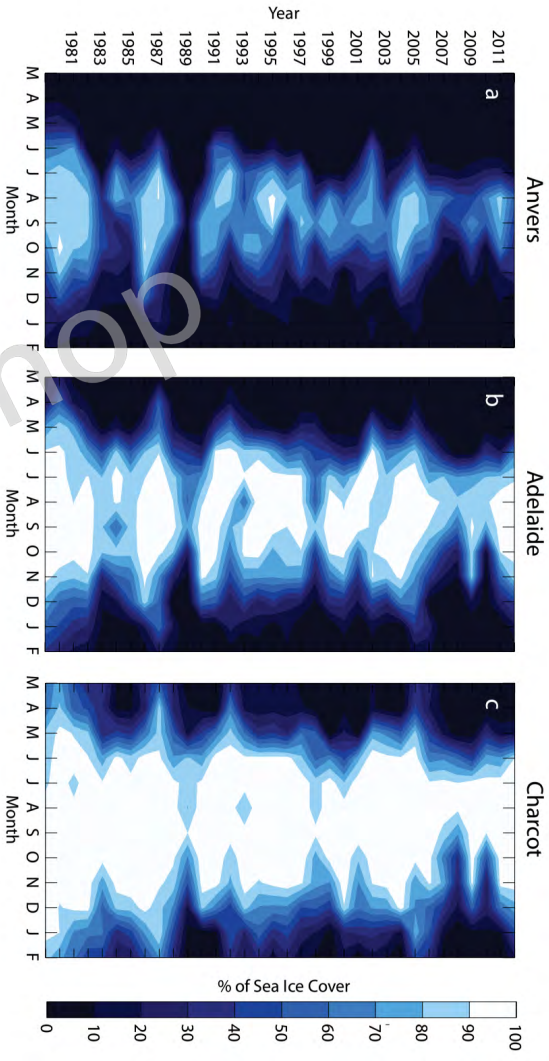


Ducklow et al. 2013

- Decreased sea ice cover means increased light – more photosynthesis



Plot: Jamie Collins



Ducklow et al. 2013

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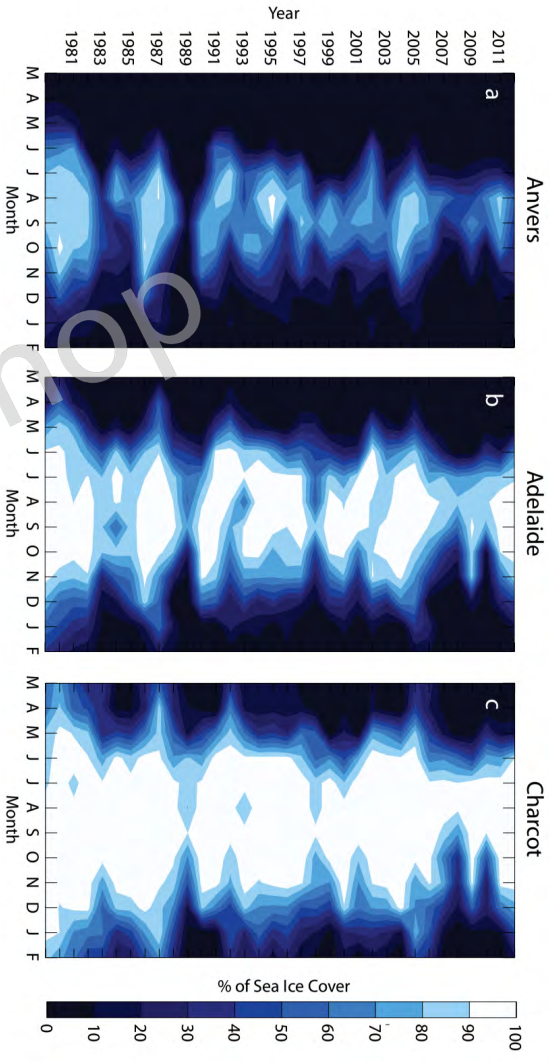
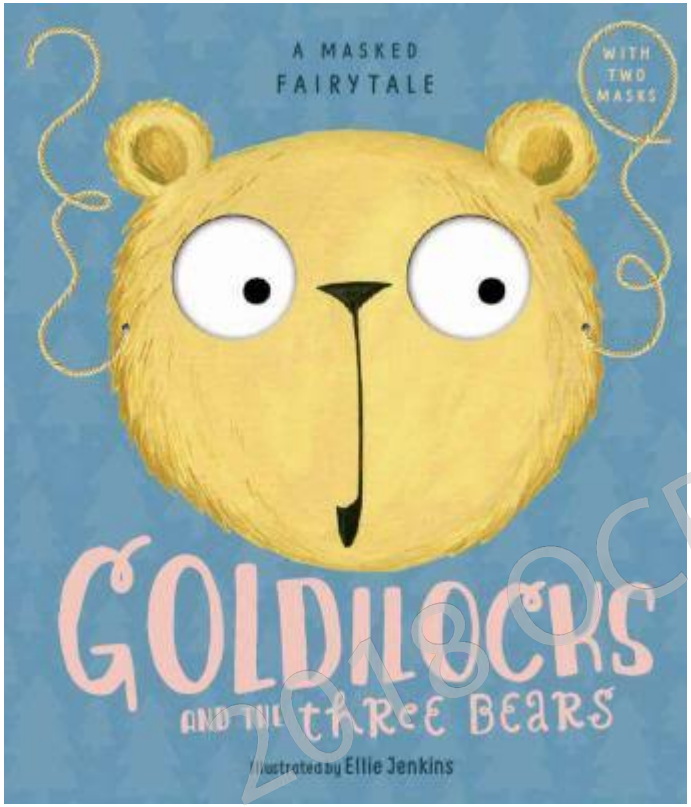
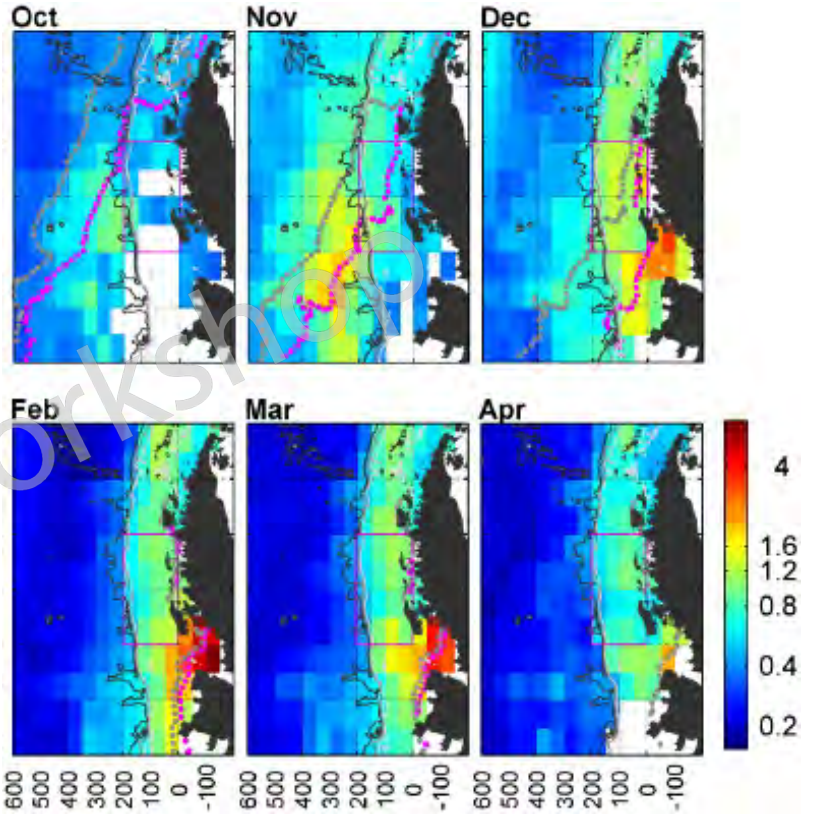


Ducklow et al. 2013

- Decreased sea ice cover means increased light – more photosynthesis
- Decreased sea ice cover also means increased vertical mixing – reduced light and increased physical losses



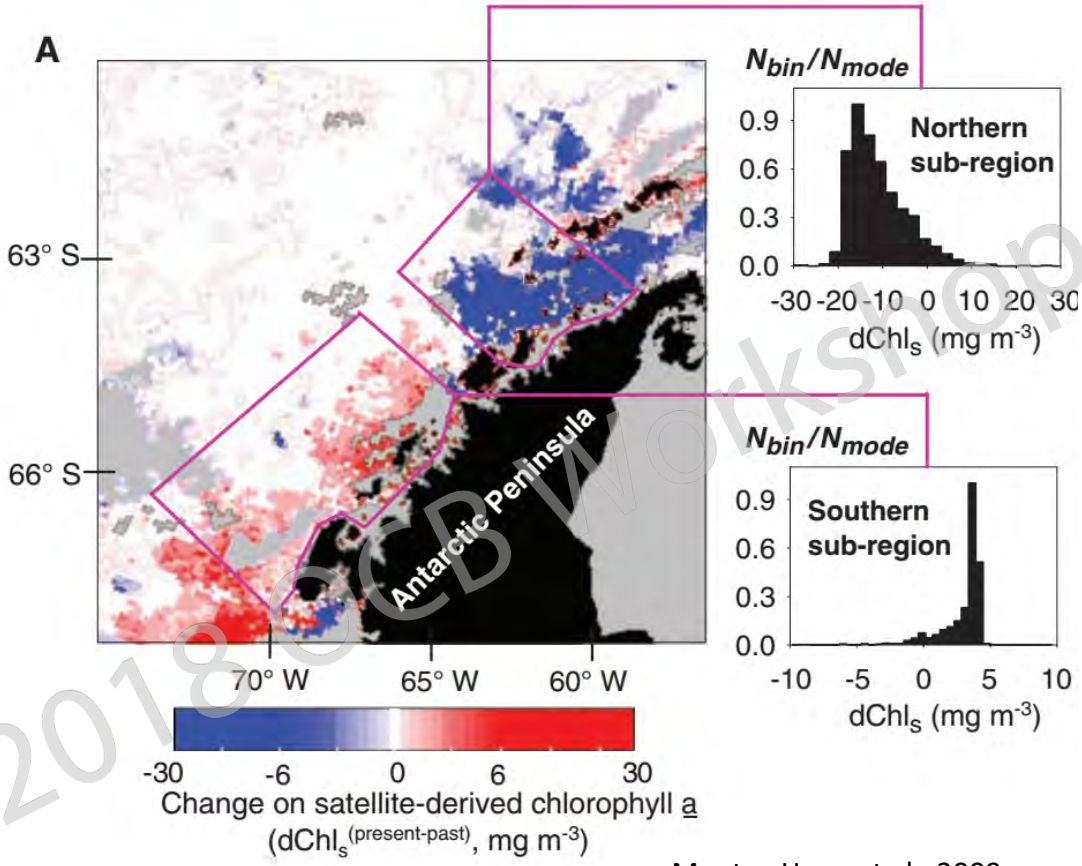
Sea ice, like porridge, needs to be just right…



Smith et al., 2008

Bloom initiates early in the spring at the sea ice edge and follows the sea ice retreat.

- Decreased sea ice cover means increased light – more photosynthesis
- Decreased sea ice cover also means increased vertical mixing – reduced light and increased physical losses

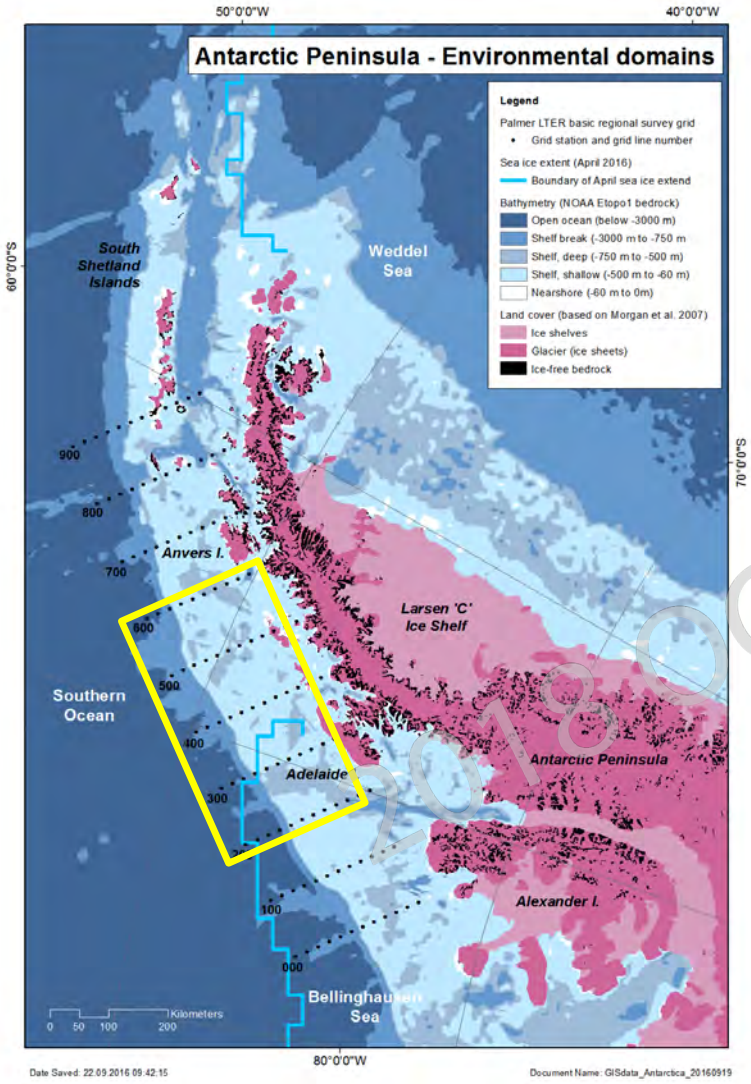


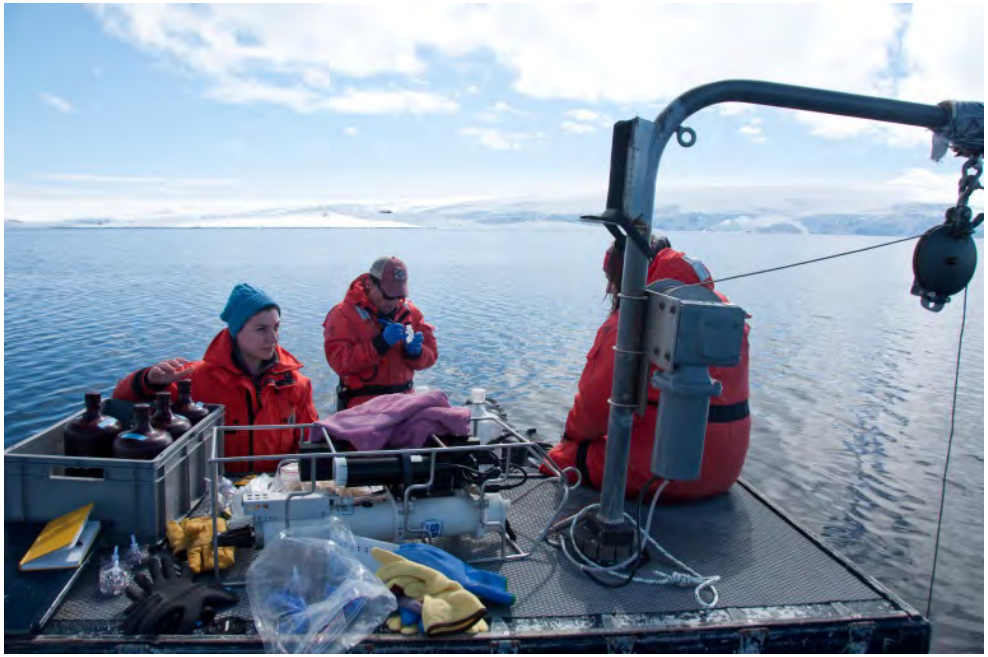
Montes-Hugo et al., 2009

Decadal shift in chlorophyll biomass from 1978-1986 and 1998-2006

- Combined effects:
  - A decrease in optimal conditions along the northern WAP?
  - An increase in optimal conditions along the southern WAP?

Exchange: An introduction to the western Antarctic Peninsula



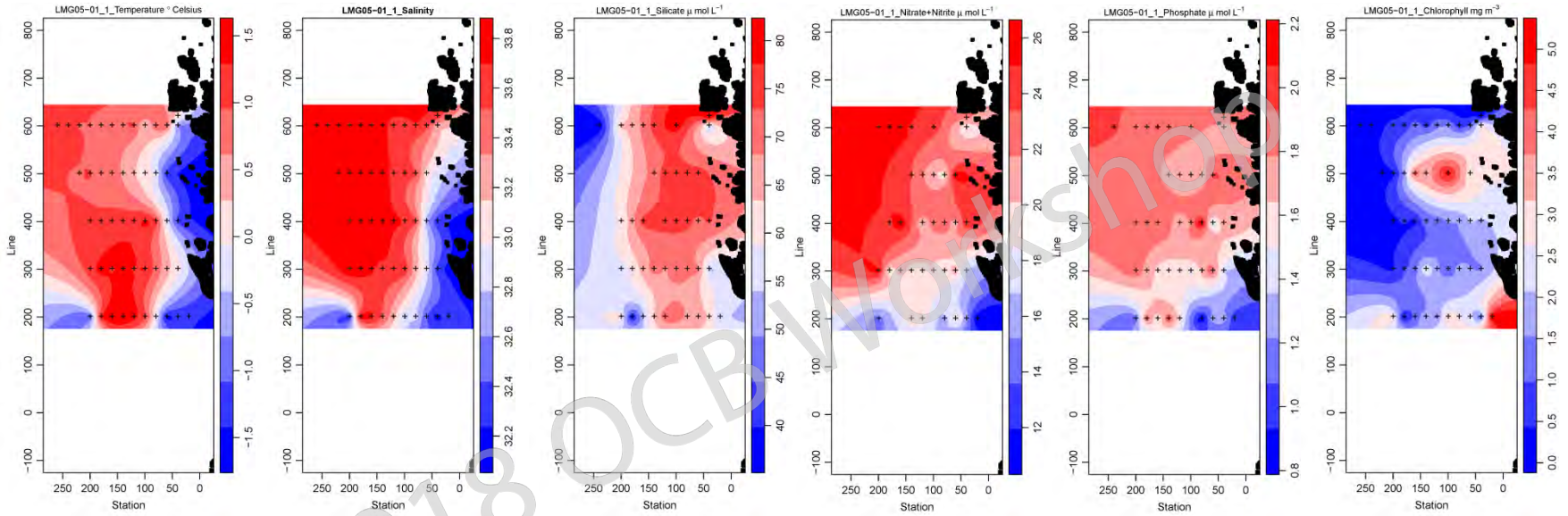


Palmer LTER has been studying ecological processes along the WAP since 1993

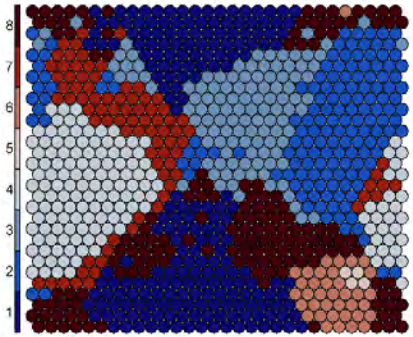
Rearrange: A seascape unit view of the WAP

To identify ecological trends we were motivated to develop a seascape unit classification approach based on key parameters collected by the LTER

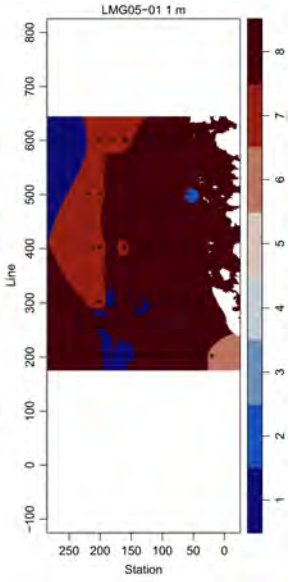
T S Si N P Chl



- T, S, macronutrients, chlorophyll a are used to train a self organizing map (SOM)
- The SOM is clustered into seascape units
- Objectively mapping the original data allows us to project the seascape units onto the LTER sampling grid
- We can then look at the distribution of seascape units across time and space



Bowman et al., 2018



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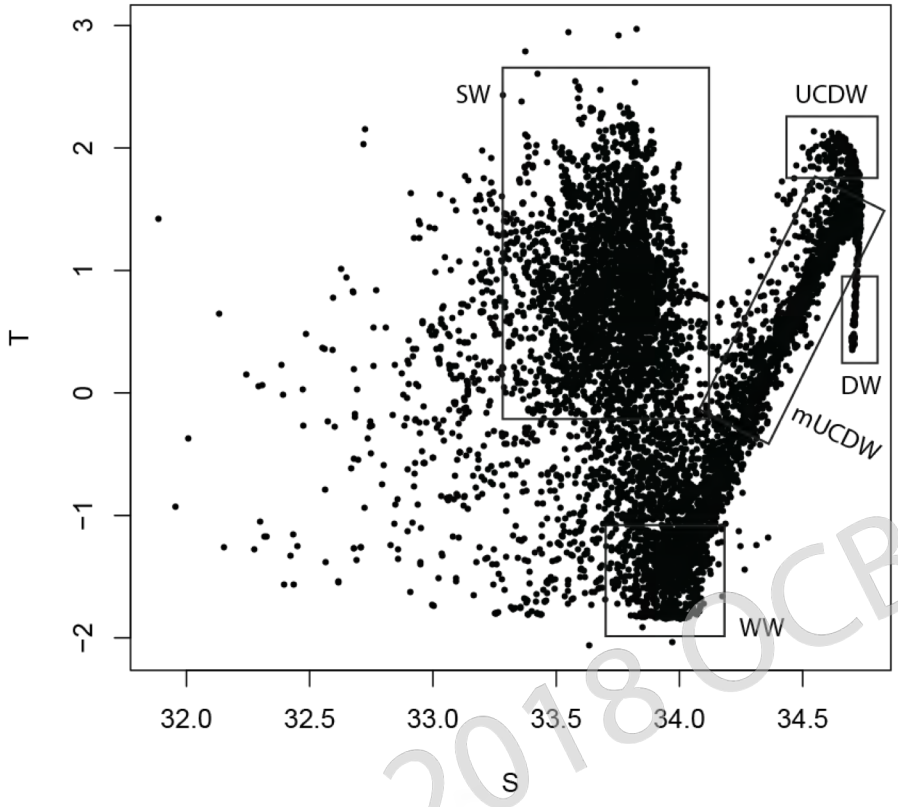

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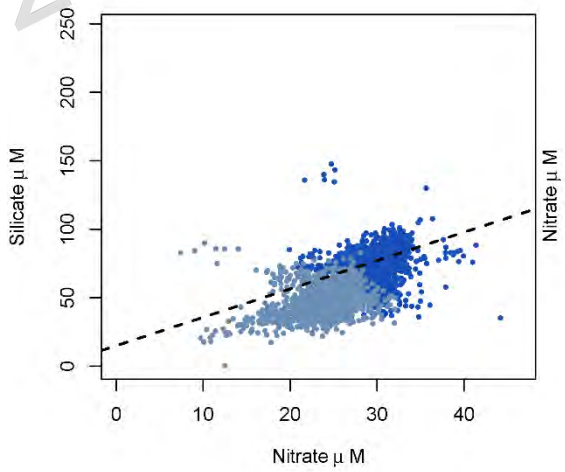
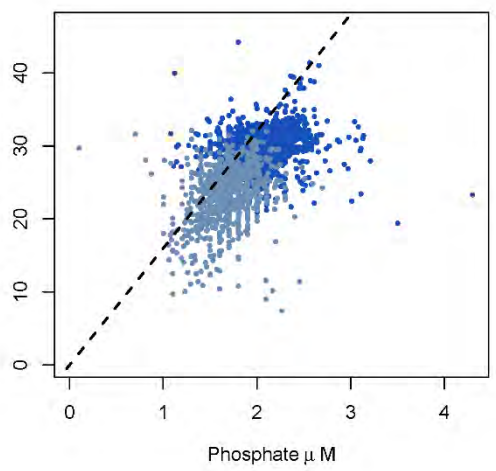
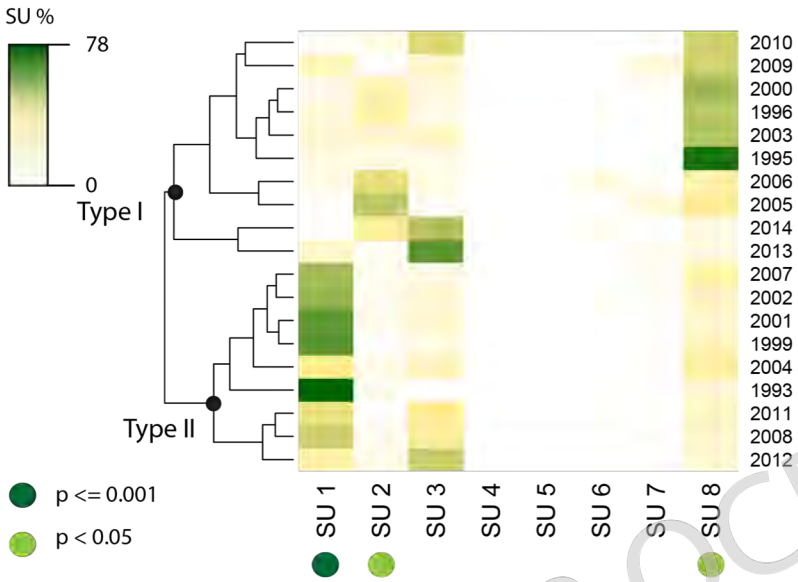
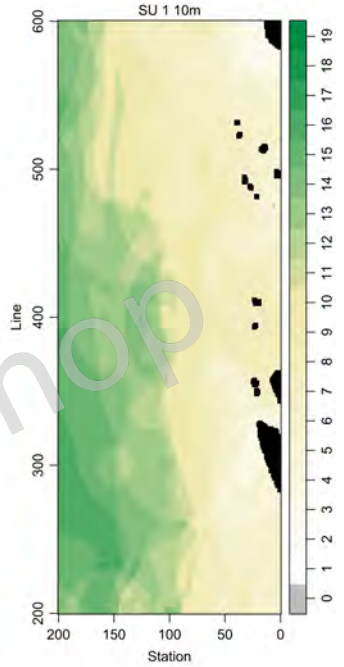


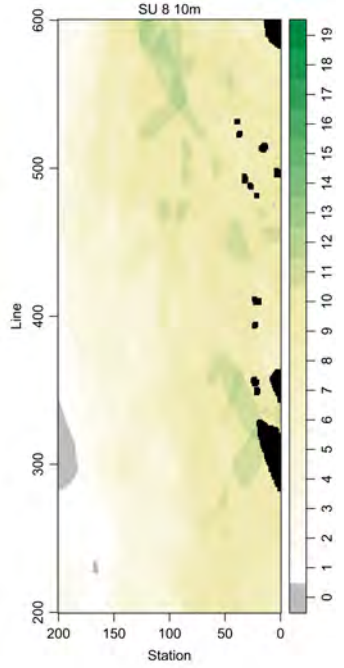


Rearrange: A seascape unit view of the WAP

a

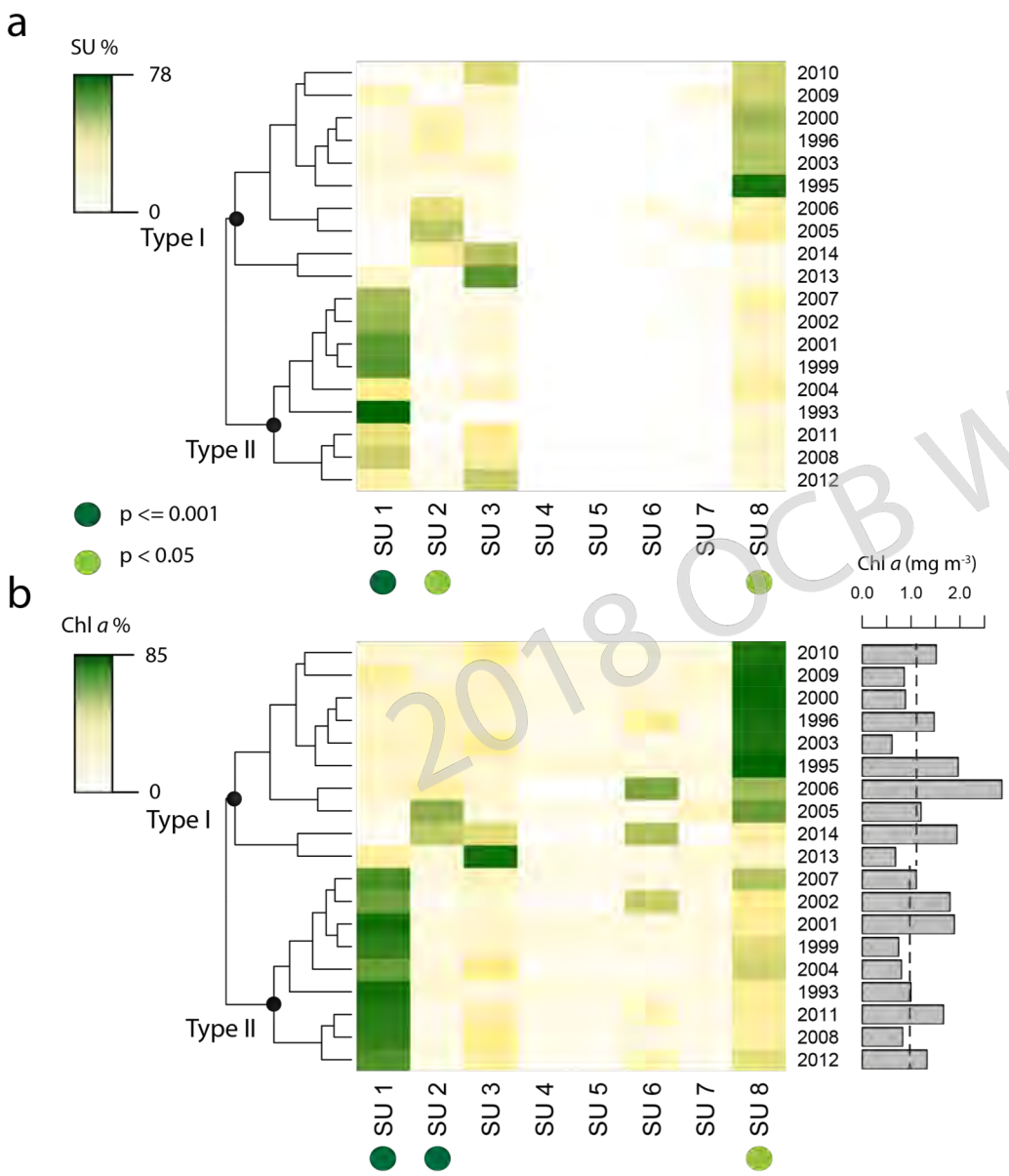


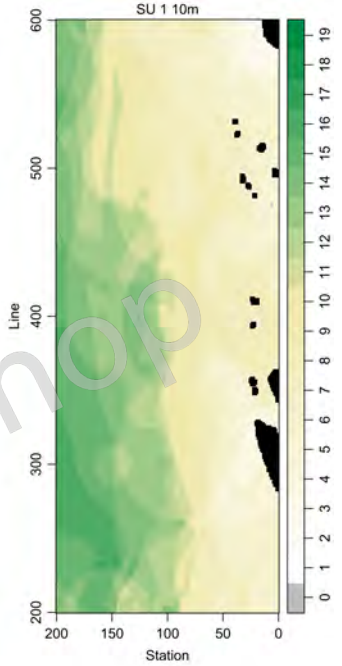


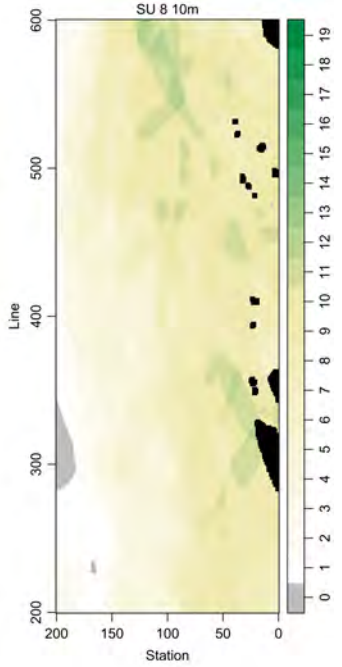


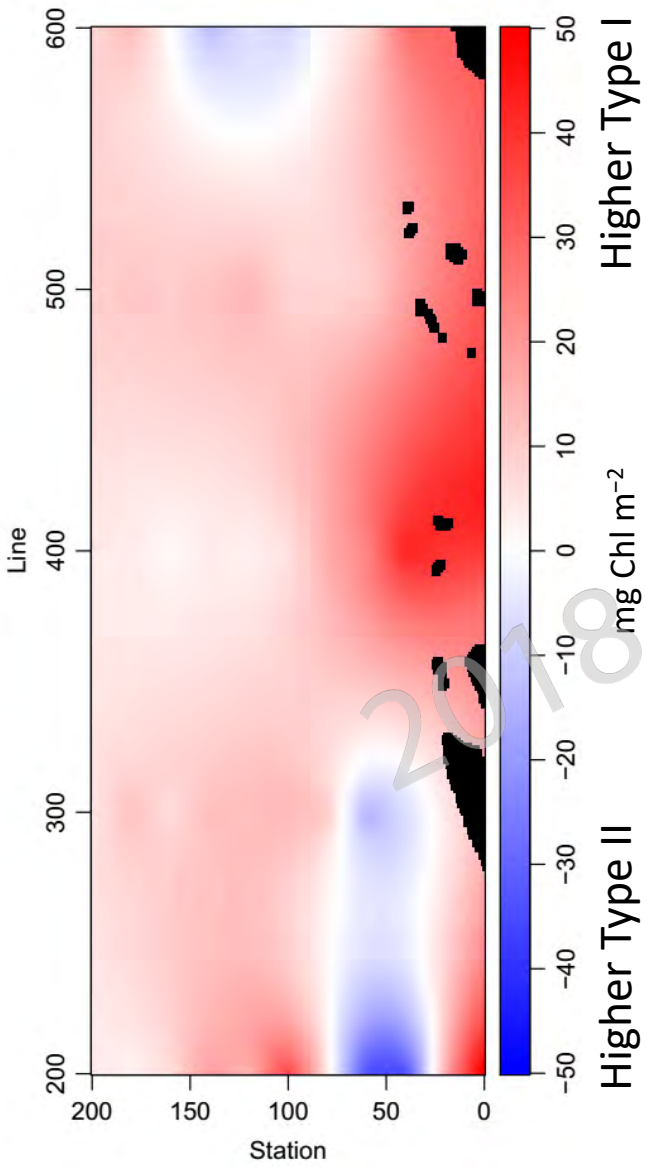
- LTER cruises form two significant clusters based on SU relative abundance
- Type I years are dominated by SU 8 or SUs 2&3
- Type II years are dominated by SU 1

Rearrange: A seascape unit view of the WAP







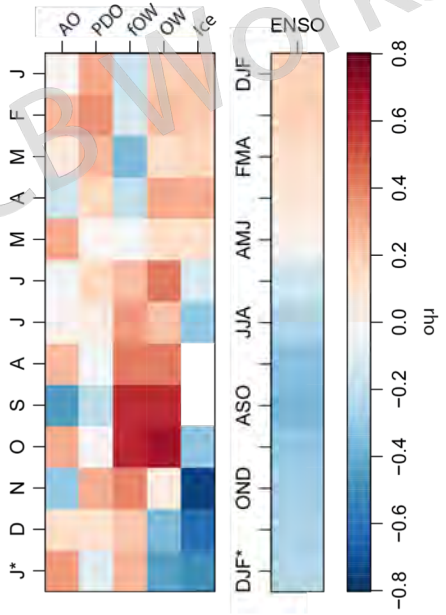


Bowman et al., 2018

What physical drivers of this system might control the distribution of SUs, and thereby determine year type?

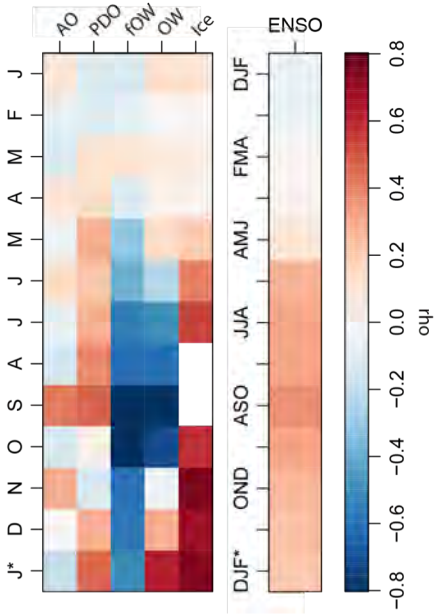
We evaluated time-lagged modes of climate variability (AO, PDO, ENSO) and ice condition (fOW, OW, Ice)

SU1



- Spring OW (+)
- Spring Ice (-)

SU2



- Spring OW (-)
- Spring Ice (+)

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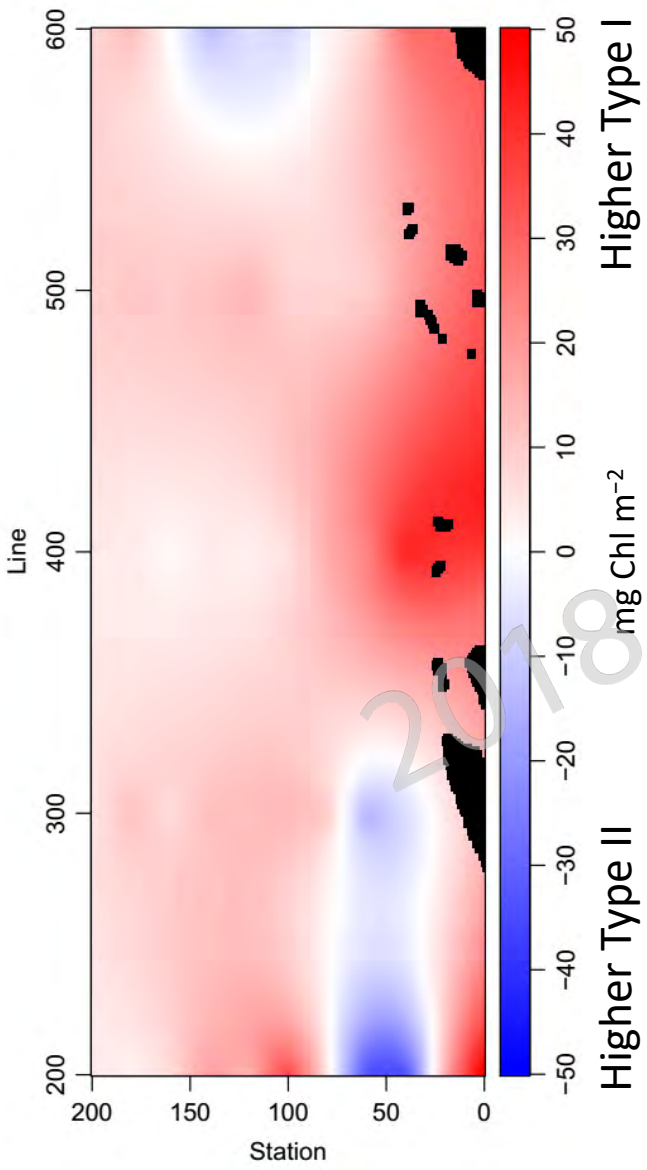

Bowman et al., 2018

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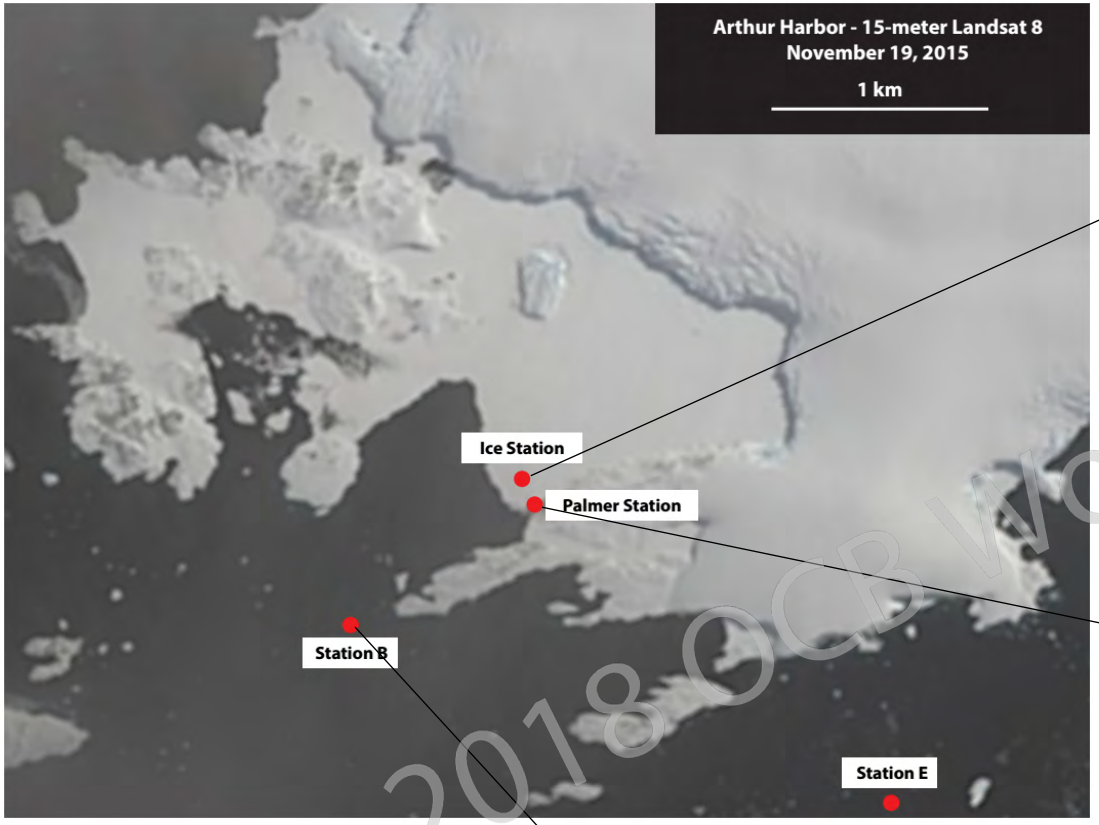
We evaluated time-lagged modes of climate variability (AO, PDO, ENSO) and ice condition (fOW, OW, Ice)

- Type I: Spring pack ice is extensive and consolidated. "Typical" nearshore conditions (SU 8) are extensive, WW (SUs 2&3) is more abundant, and more chlorophyll is observed in the nearshore.
- Type II: Spring pack ice is reduced and fragmented. "Typical" offshore conditions (SU 1) are extensive, WW (SUs 2&3) is less abundant, and more chlorophyll is observed mid-shelf.
- **This may result from a suppression of an earlier bloom by wind in Type II years.**
- **Spring ice conditions – well beyond the observational horizon of the LTER cruise – can exert a strong impact on the ecosystem in January**

Change: Patterns in gene expression during the polar spring



No wind, no light

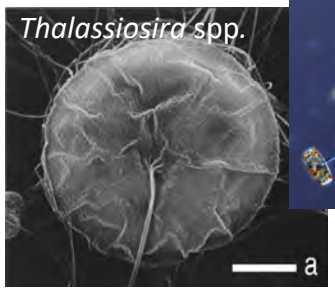
Light, no wind

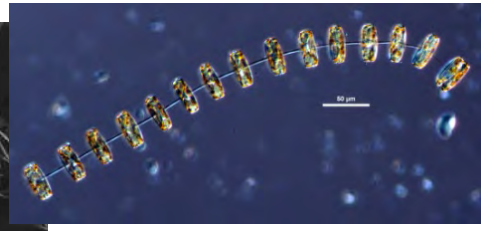
Moderate light and wind

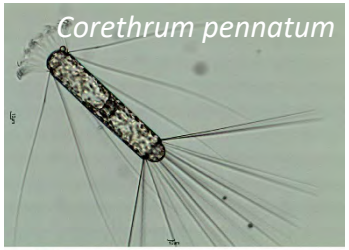
Ice Station	Station B	Station E	Incubations	Time (days)
A				-7
B			B	0
			C	2
E			D	4
	F			6
			G/H	7
I				14
	L	J/K		15
N				19
	O			22
	R			27
	W			34

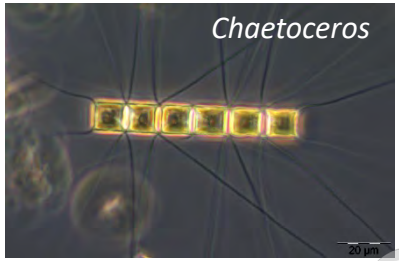
In spring of 2015, unusual ice conditions provided an opportunity to study the evolution of the spring bloom below sea ice and in the ne marginal ice zone

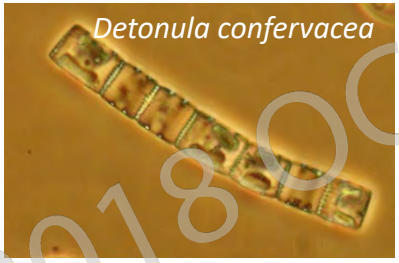
Change: Patterns in gene expression during the polar spring



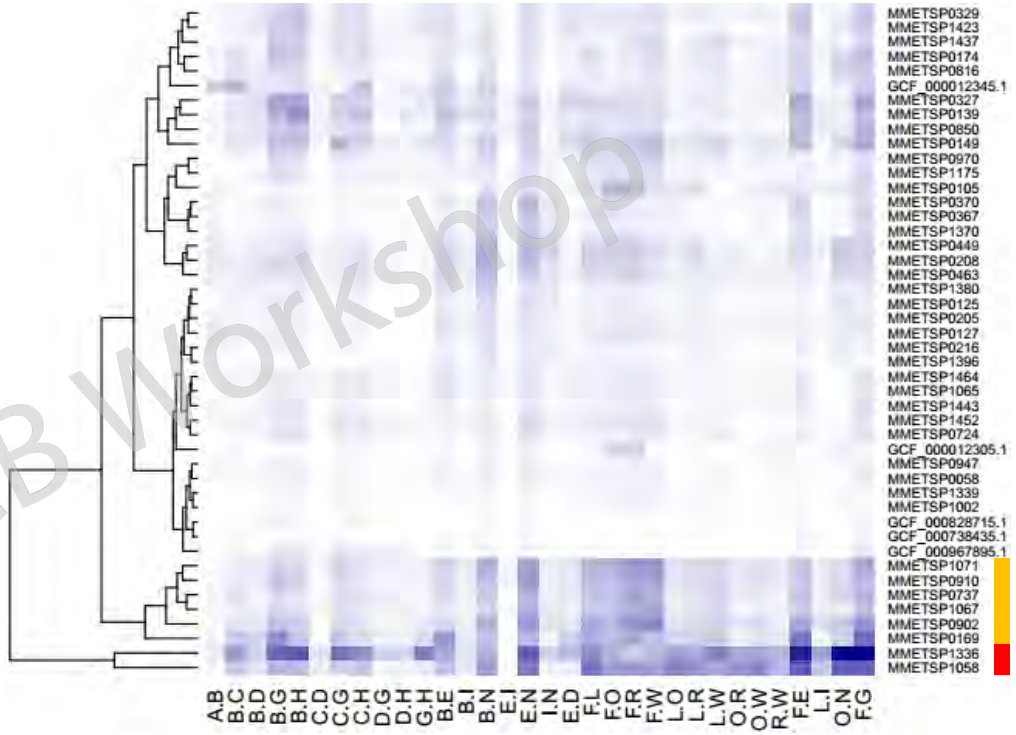








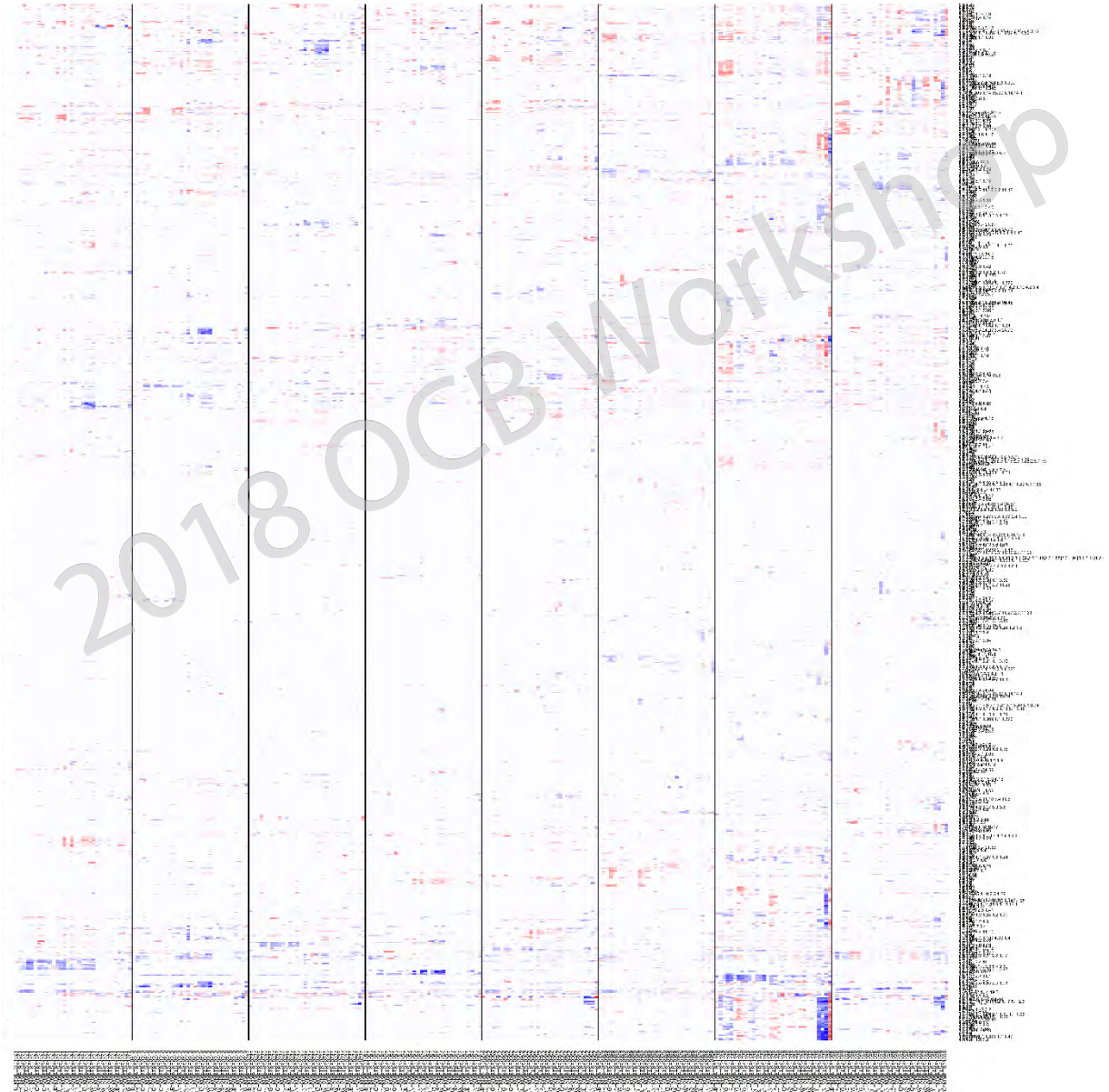
Strength of response as inferred from the number of differentially expressed genes



MMETSP1071: *Thalassiosira* sp.
MMETSP0910: *Thalassiosira rotula*
MMETSP0737: *Thalassiosira miniscula*
MMETSP1067: *Thalassiosira punctigera*
MMETSP0902: *Thalassiosira antarctica*
MMETSP0169: *Corethron pennatum*
MMETSP1336: *Chaetoceros neogracile*
MMETSP1058: *Detonula confervacea*

Ice Station	Station B	Station E	Incubations	Time (days)
A				-7
B			B	0
			C	2
E			D	4
	F			6
			G/H	7
I				14
	L	J/K		15
N				19
	O			22
	R			27
	W			34

All differentially expressed genes for select transcriptomes
(5664 enzymes observed, 1077 differentially expressed)



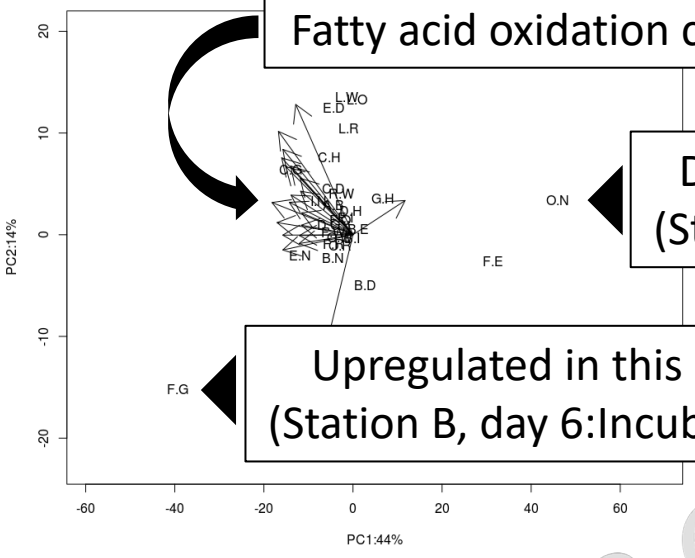
Chaetoceros neogracile

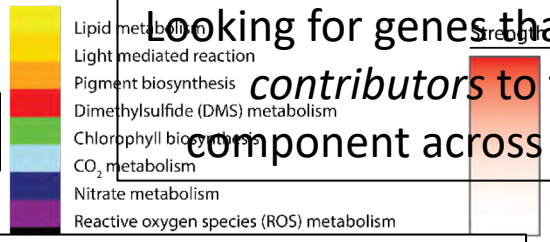
Looking for genes that are *consistent major contributors* to the first principal component across genomes of interest

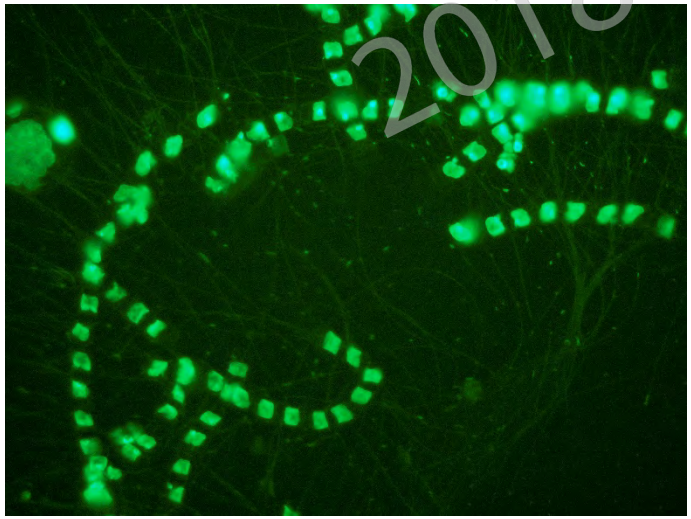
Fatty acid oxidation complex

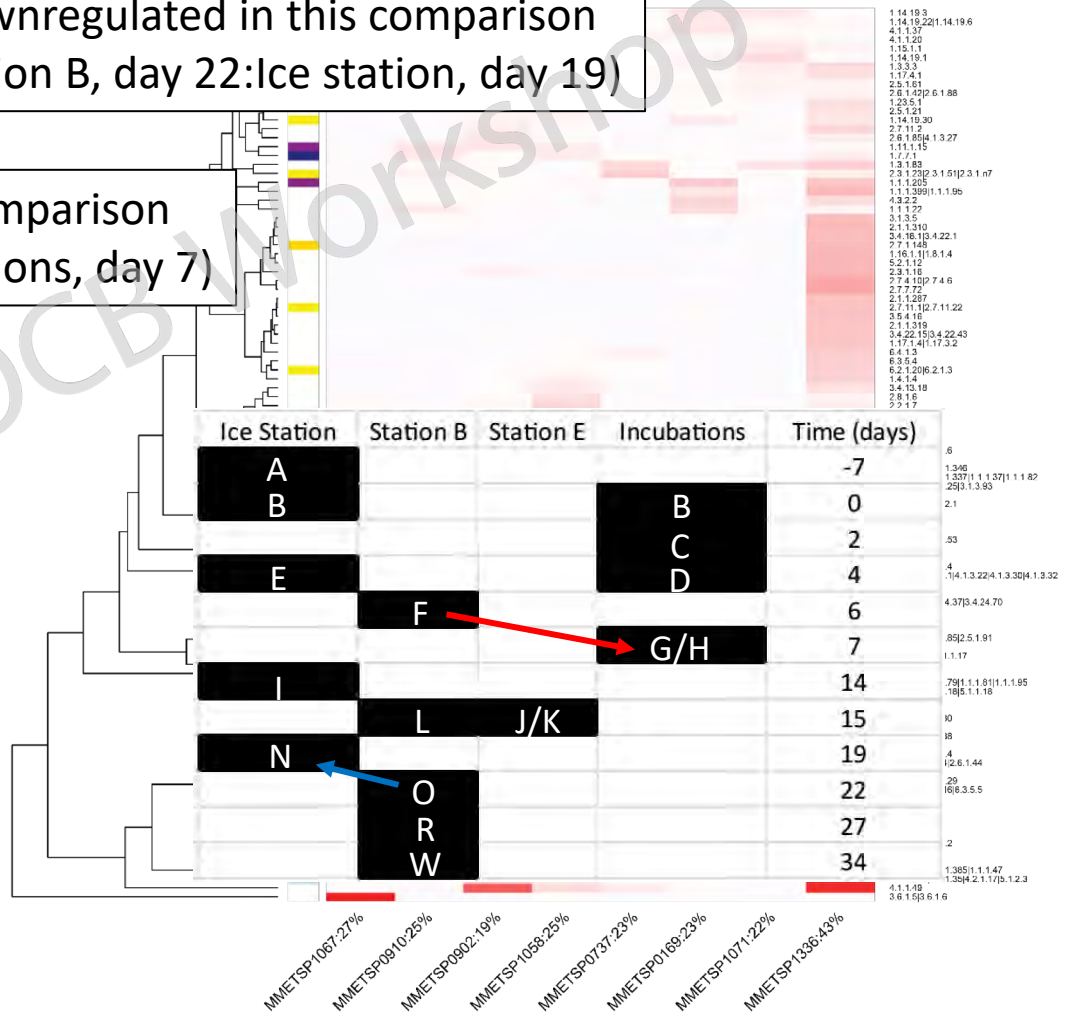
Downregulated in this comparison
(Station B, day 22:Ice station, day 19)

Upregulated in this comparison
(Station B, day 6:Incubations, day 7)

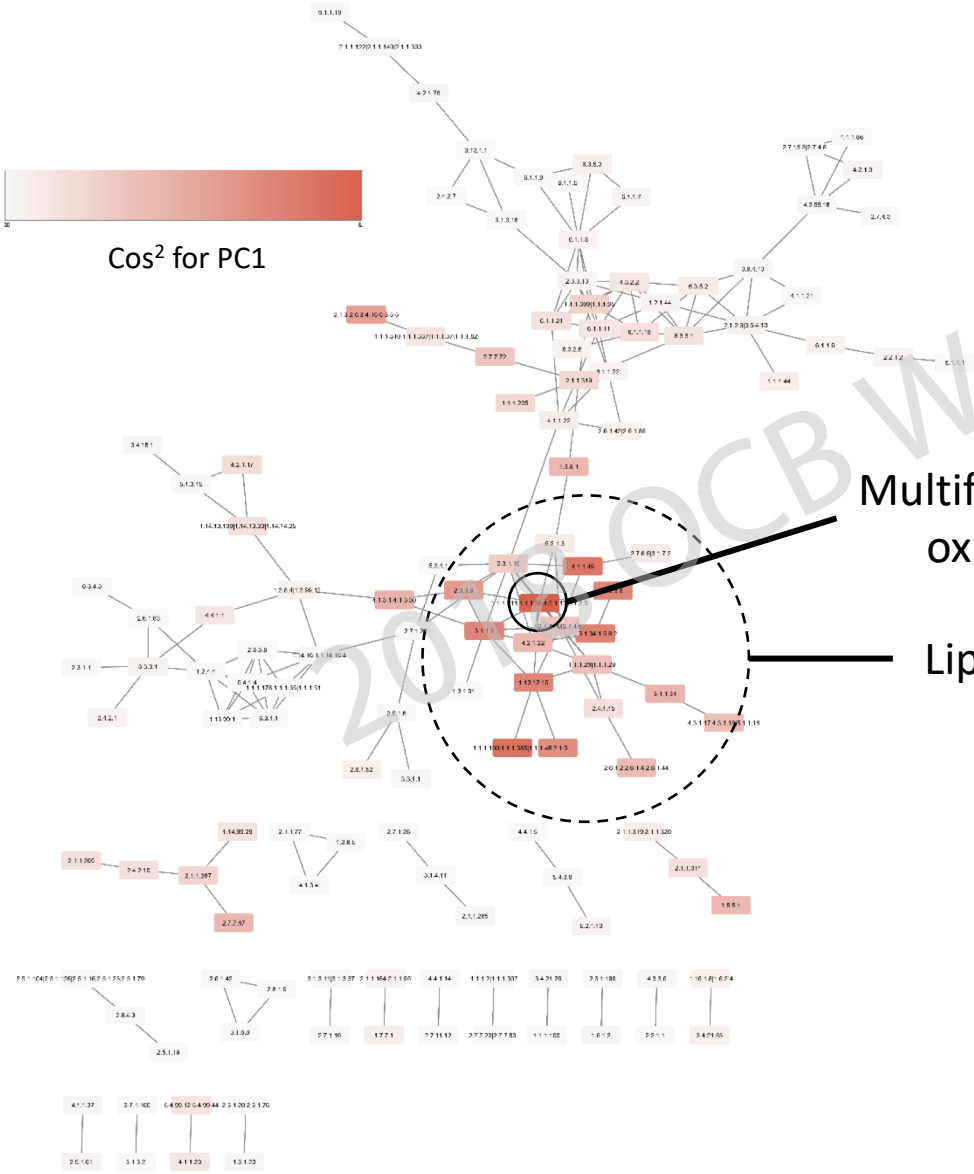








WGCNA for *C. neogracile*,
based on differential expression pattern



Hypothesis: Lipid stores are rapidly consumed when (stable) preferential growth conditions are encountered.

Summary

- **Exchange:**
  - **The marine ecosystem of the WAP is changing rapidly in response to shifting climatic conditions and changing trophic structures.**
  - **Changing sea ice conditions can have positive and negative effects on the development of the spring bloom.**
- **Rearrange:**
  - **Seascape units provide a way to identify trends that may not be identifiable by observing individual parameters alone.**
  - **Specifically, the onshore-offshore distribution of chlorophyll is strongly dependent on the distribution of seascapes.**
- **Change:**
  - **Gene expression analysis can be used to identify specific physiological responses to the presence or absence of sea ice.**
  - **For example, genes associated with lipid catabolism are dramatically up-regulated in the absence of sea ice. This suggests that phytoplankton quickly consume their energy stores as they emerge from polar darkness.**

Acknowledgements

- The Palmer LTER program
- The crew of the ARSV *Laurence Gould*
- The science support staff at Palmer Station
- Collaborators on seascape project
  - Hugh Ducklow (LDEO)
  - Scott Doney (UV)
  - Maria Kavanaugh (OSU)
- Collaborators on gene expression project
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  - Ben Van Mooy (WHOI)
  - Colleen Hansel (WHOI)
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